wish to propose an amendment to place the claims in better condition for allowance, the Examiner should feel free to contact the undersigned at (414) 276-0977.

Our check in the amount of $350.00 for the addition of two (2) new independent claims and thirty (30) more claims over 20 was previously submitted to the United States Patent and Trademark Office on April 27, 2001, along with the initial Preliminary Amendment which was rejected.

If there is any additional fee due in connection with the filing of this Preliminary Amendment, or any overpayment made, please charge the fee or credit the overpayment to our Deposit Account No. 14-1080.

Respectfully submitted,

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## IN THE SPECIFICATION

Please amend the application as follows, with deleted items being shown as **[bracketed]** and additions being **underlined**, as follows:

Page 2, paragraph 2 (lines 16-28):

According to another known type of tire sensing device, a number of toroidal bands of piezoresistive or piezoelectric **[elastomer]** **material** are disposed in the tread of the tire. Notably, the measurement obtained by this device is not localized to a **[signal]** **single** tread block, and as a result, suffers from undesirable effects due to centrifugal force, road surface irregularities, and pressure changes. In yet another sensor device for monitoring tires, reed sensors incorporating strain gauges are employed, each sensor measuring forces directed in a single axis. In this arrangement, three separate devices, disposed at three separate locations, are required to obtain three axes of traction data. A significant problem associated with such a device is that each individual tread block will experience forces from the three axes concurrently. Typically, each tread block acts independently in a stick-slip fashion. As a result, measuring X axis data from one tread block, Y axis data from an adjacent tread block and Z axis data from yet another location, will yield three axes of data that is of little use.

Page 8, paragraph 3 (lines 21-26):

Using sensor assembly 20 to obtain a measure of both the shear force in the X direction and the shear force in the Y direction, as described above, a compressive force along the Z-axis can be determined. In particular, the compressive force in the Z direction is equal to the sum of the tensile strains measured by sensors 22, 24, **[26]** **30**, and **[28]** **32**. In this way, a separate sensor arrangement for measuring compressive force is not required.

Page 12, paragraph 3, lines 28-29 bridging page 13, lines 1-15:

In Figure 8, the components of a sensor assembly 40' are shown arranged according to a preferred embodiment. Sensor assembly 40' includes a flexible pyramid-

shaped body or insert 70 that is bonded to a surface 74 of a substrate 76 of a flexible printed circuit 72, preferably with an adhesive 77. Printed circuit 72 is fabricated with electrical conductors disposed in an epoxy or polyimide substrate 76, while strain sensors 22, 24 (which measure shear strain in a first direction, for example, the x direction) are electrically attached to flexible printed circuit 72 via a connection 78. Moreover, sensors 22, 24 are bonded to surfaces 80, 82, respectively, of flexible pyramid-shaped body 70, preferably by **an adhesive such as an** epoxy 71. Similar connections are made for a second pair of sensors (not shown) that measure strain forces in a second direction orthogonal to the first direction, for example, the y direction as shown in Figure 4. Alternatively, substrate 76 could be a silicon integrated circuit (IC) fabricated in conventional fashion. The entire sensor assembly 40' may optionally be potted or coated in a material 84 such as an epoxy or some other material suitable to the user, for example, to scale the strain forces exerted on sensors 22, 24, as discussed in further detail below in conjunction with one preferred application of the present invention.

Page 13, paragraph 3, lines 29-31 bridging page 14, lines 1-7:

Referring next to Figure 10, as suggested previously, **[one particularly suitable]** **a preferred** application of the sensor of the present invention is in a tire monitoring environment. Figure 10 illustrates a cross sectional view of tread rubber portion 112 of a tire 110. A tread block 114 is shown having a device 116 including sensor assembly (for example, 40 in Figure 5) embedded therein. Notably, device 116 is shown as a square and is oriented to indicate the portion of tread block 114 that is represented in the strain diagrams of Figures 2 and 3. Preferably, device 116 is located in a tread block at or near the center portion of the cross-section of the tire so as to ensure the device measures forces acting in the contact region of the tire.

Page 15, paragraph 1, lines 1-12:

Notably, the operating range of the sensor must be considered in the manufacturing process. The tread rubber in the position to be measured will experience a maximum shear strain of about 10%, or 100,000 micro strains. Taking a typical foil type

resistive strain gauge for example, fatigue and failure will occur if the gauge is repeatedly overstrained. At 1500 micro strain, the gauge will fail after about a million cycles, which would occur in about a thousand miles in a tire. At 1200 micro strain, the gauge will last approximately 100,000 miles. Generally, the amount of strain experienced by a device embedded within another material is related to the ratio of the elastic modulus of the materials. Tread rubber has a modulus of elasticity of about 3-7 Mega Pascals. The foil gauge is preferably encapsulated in polyimide or epoxy (as shown, for example, in Figure 8 at **[84]** 83) which has a modulus of elasticity of about 3-7 Giga Pascals, thus providing a scale factor of about 1000.

Page 15, paragraph 2, lines 13-22:

Overall, the amount of strain incurred by the sensor assembly including metal resistor strain gauges can be scaled by one or more of the three following components: the dimensions or composition of the pyramid-shaped body (for example, 42 in Figure 5), the strain gauge encapsulation, or the adhesive or potting material. Alternatively, or in combination with one or more of these components, a topping or coating layer **(*e.g.*, 85 in Figure 8)** may be added to further scale the strain exerted on the sensor. The topping, for example, may be brass. In the case where the strain sensor is not a metal resistor, these components, including the topping layer, may still be used to scale the strain at the sensor, however, other types of sensors, such as some of those described above, may not incorporate encapsulation.

Page 16, paragraph 2, lines 7-24:

Moreover, encapsulation, adhesive, and potting may comprise three different materials, or may be reduced to one or two unique materials, thereby combining their form and functions. First, metal foil type strain gauges **22, 24, 30, 32** are often provided with epoxy or polyimide encapsulation. Next, the sensor must be adhered to the pyramid-shaped body by some means. Adhesion between the components of the device is vital for its survival. The components may be of different materials with different elastic properties. The adhesive must bond these components and withstand billions of

strain cycles without failure. Some materials which meet these requirements include epoxy, polyimide and polyurethane. Epoxy is the preferred adhesive because of its ability to adhere well and remain temperature resistant. The adhesive is preferably applied as a thin layer between components, such as between the body and the sensors. Otherwise, in addition to the thin layer of adhesive between components, an excess may be applied, such that the assembly is potted, partially or entirely, with the adhesive to insure a uniform and controllable outer surface **(84 in Figure 8, for example)**. Alternatively, two different materials may be used for adhesion between components and for potting, respectively. Notably, however, the outermost surface (e.g., the potting) of the three-axis device should be of a material that is compatible with the embedding and curing process.

Page 17, paragraph 3, lines 14-20:

PZT (lead zirconium titanate) sensors, schematic shown in Figure 1C, can be used in place of resistive strain gauges in order to save power. PZT is brittle yet highly sensitive. To bring the strain into the range of these devices, the pyramid-shaped body is made of a relatively hard epoxy, and the **[sensor assembly]** **sensors** is preferably encapsulated in the same epoxy. In one arrangement, the device could be assembled from four individual piezo crystals. Otherwise, PZT could be deposited on the body itself, or on a substrate to be formed into a pyramid-shaped body.

Page 17, paragraph 4, lines 21-29:

In Figure 11, multiple devices 116 (Figure 10) including sensor assemblies (for example, 40 in Figure 5) are distributed around the circumference of tire 110. Any number of sensor assemblies may be employed. Preferably, the sensors are separated sufficiently along the circumference such that only one sensor is allowed to pass through the tire's contact region at any particular time. Notably, an increase in the number of sensor assemblies will decrease the sensitivity of any one sensor assemblies if they are summed or averaged together as in the case with any of the sensor busses described hereinafter. The preferred number of sensors is between 3 and 10.

Page 21, paragraph 2, lines 11-18:

Referring to Figure 20, in an alternative to the mounting of the silicon IC underneath the pyramid-shaped body of the sensor assembly shown in Figures 18 and 19, a silicon IC **[222]** 202 is mounted adjacent to the body of sensor assembly 220. Figure 20 shows IC **[222]** 202 mounted on the opposite side of the substrate 76 relative to the mounting of the pyramid-shaped body 70, while Figure 21 illustrates an IC **[222]** 202 being mounted on the same side of substrate 76 as the pyramid-shaped body 70. In either case, the IC 202 in Figures 20 and 21 may be connected through direct electrical bonding as in Figure 18, or by wire bonding as in Figure 19.

## IN THE CLAIMS:

Please amend Claim 1 as follows:

1. A **[three-axis]** sensor assembly for use in an elastomeric material, the **[sensor]** **assembly** comprising:

a first pair of sensors disposed along a first pair of respective **[axes]** **planes** that intersect, said first sensors detecting a force in a first direction;

a second pair of sensors disposed along a second pair of respective **[axes]** **planes** that intersect, said second sensors detecting a force in a second direction **[generally orthogonal to the first direction]**; and

wherein the force measured in the first direction is equal to the difference between the outputs of said first sensors, and the force measured in the second direction is equal to the difference between the outputs of said second sensors.

Please amend Claim 2 as follows:

2. The **[three-axis]** sensor assembly of Claim 1, wherein the sum of the **[outputs of]** **forces on** said first sensors and said second sensors equals a force in a third direction **[orthogonal to said first and second directions]**.

Please amend Claim 3 as follows:

3. The **[three-axis]** sensor **assembly** of Claim 1, wherein said first pair of respective axes are generally oriented at a first angle with respect to the first direction.

Please amend Claim 4 as follows:

4. The **[three-axis]** sensor assembly of Claim 3, wherein said second pair of respective axes is generally oriented at a second angle with **[respective]** **respect** to the second direction.

Please amend Claim 5 as follows:

5. The **[three-axis]** sensor assembly of Claim 4, wherein said first and second angles are equal.

Please amend Claim 17 as follows:

17. The sensor assembly of Claim 16, wherein **said** body is made of one polyamide, urethane and epoxy.

Please delete Claims 24-28 as follows:

**[24. The sensor assembly of Claim 23, wherein the object is a tire.]**

**[25. The sensor assembly of Claim 24, further including a bus to communicate signals generated by the plurality of sensor assemblies.]**

**[26. The sensor assembly of Claim 25, wherein said bus is a five-wire bus.]**

**[27. The sensor assembly of Claim 24, wherein a contact region is defined at a position where the tire contacts a surface.]**

**[28. The sensor assembly of Claim 27, wherein, when the tire is operation, each of the plurality of sensors passes said contact region at a different time.]**

Please amend Claim 30 as follows:

30. A process of embedding a **[three axis]** sensor in an elastomeric material, the process comprising:

providing a three-axis sensor **assembly** including two pairs of strain gauges, a first pair disposed on first opposed faces of a pyramid-shaped body**,** and**[,]** a second **[select]** pair disposed on second opposed faces of **[said]** **the** pyramid-shaped body; **and**

adjusting the aspect ratio of the pyramid**-shaped body** to **[the]** **a** sensitivity of the three-axis sensor.

Please amend Claim 31 as follows:

The process of Claim 30**,** further including the step of adjusting the hardness of the pyramid-shaped body relative to the elastomeric material.

Please amend Claim 33 as follows:

33. The process of Claim 30, further including the step of encapsulating **[three-axis sensor]** **the first and second pairs of strain gauges** in a second material different than the elastomeric material.

Please add the following **new** Claims 36-70 as follows:

36. The process of Claim 35, further including the step of coupling the strain gauges to the body with an adhesive.

37. The process of Claim 36, further including the step of potting the sensor assembly in a third material.

38. The process of Claim 37, wherein the adhesive and the third material are the same.

39. The process of Claim 30, further including the step of placing a topping layer on the sensor assembly so as to scale strain forces sensed by the strain gauges.

40. The three-axis sensor assembly of Claim 10, wherein said first sensing element comprises a first pair of strain sensors, and said second sensing element comprises a second pair of strain sensors.

41. The three-axis sensor assembly of Claim 40, wherein said first sensing element is disposed on a first pair of generally opposed faces of a pyramid-shaped body, and said second sensing element is disposed on a second pair of generally opposed faces of the pyramid-shaped body.

42. The three-axis sensor assembly of Claim 41, wherein said first and second pairs of strain sensors are resistive strain sensors.

43. The three-axis sensor assembly of Claim 42, wherein said first and second sensing elements generate said first and second outputs differentially.

44. The three-axis sensor assembly of Claim 43, wherein said first and second sensing elements are arranged in a Wheatstone bridge circuit to generate said first and second outputs.

45. A process of embedding a sensor in an elastomeric material, the process comprising:

providing a three-axis sensor assembly including first and second pairs of strain sensors, the first pair disposed on first opposed faces of a pyramid-shaped body, and the second pair disposed on second opposed faces of the pyramid-shaped body; and

placing the sensor assembly in the elastomeric material when the elastomeric material is in an uncured state.

46. The process of Claim 45, further comprising the step of adjusting the aspect ratio of the pyramid-shaped body according to a sensitivity of the sensor assembly.

47. The process of Claim 45, further comprising the step of encapsulating the first and second pairs of strain sensors.

48. The process of Claim 47, wherein said encapsulating step includes using a second material different than the elastomeric material.

49. The process of Claim 48, further comprising the step of selecting a ratio of elastic moduluses between the elastomeric material and the second material.

50. The process of Claim 49, wherein the second material is one of polyimide and epoxy.

51. The process of Claim 48, further including the step of coupling the strain sensors to the pyramid-shaped body with an adhesive.

52. The process of Claim 51, further including the step of potting the sensor assembly in a third material.

53. The process of Claim 52, wherein the elastomeric material, the second material, the third material and the adhesive are different.

54. The process of Claim 52, further including the step of placing a topping layer on the sensor assembly so as to scale strain forces sensed by the strain sensors.

55. The process of Claim 45, further comprising the step of adjusting the hardness of the pyramid-shaped body relative to the elastomeric material.

56. The process of Claim 45, further comprising the step of coupling the pyramid-shaped body to a printed circuit.

57. The process of Claim 56, wherein the printed circuit is flexible.

58. The process of Claim 56, wherein the printed circuit includes a substrate and said coupling step includes coupling the pyramid-shaped body to the substrate.

59. The process of Claim 58, wherein the substrate comprises a silicon IC.

60. The process of Claim 59, wherein the substrate further comprises one of a polyimide and an epoxy.

61. The process of Claim 60, further comprising the step of electrically coupling the strain sensors to the printed circuit.

62. The process of Claim 58, wherein the substrate includes generally planar top and bottom surfaces, and the pyramid-shaped body is coupled to the top surface.

63. The process of Claim 62, further comprising the step of disposing an integrated circuit on the bottom surface when the strain sensors are piezoelectric strain sensors.

64. The process of Claim 63, further comprising the step of electrically coupling the integrated circuit to the printed circuit.

65. The process of Claim 63, wherein the integrated circuit is displaced from the pyramid-shaped body.

66. The process of Claim 63, wherein the integrated circuit includes a buffer amplifier.

67. The process of Claim 45, further comprising the step of coupling the resistive strain sensors to the opposed faces with an adhesive.

68. The process of Claim 67, wherein the adhesive is an epoxy.

69. A three-axis sensor assembly embedded in an elastomeric material that measures strain forces on the elastomeric material, the sensor assembly comprising:

a three-axis sensor assembly including two pairs of strain sensors, a first pair disposed on first opposed faces of a pyramid-shaped body, and a second pair disposed on second opposed faces of the pyramid-shaped body;

a printed circuit responsive to the outputs of said strain sensors to generate a signal indicative of a strain force acting on the elastomeric material; and

wherein the sensor assembly is electrically coupled to the printed circuit.

70. The three-axis sensor assembly of Claim 69, wherein the strain sensors are resistive strain sensors.

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